

# CLAIMS

1 1. A method of operating a laser to obtain an output pulse of laser radiation having a  
 2 single wavelength, the laser including a resonator, a gain medium positioned inside the  
 3 resonator and a pump source, the method comprising:  
 4 inducing an intracavity loss into the resonator, the loss being an amount that  
 5 prevents oscillation during a time that energy from the pump source is being stored in the  
 6 gain medium;  
 7 building up gain with energy from the pump source in the gain medium until  
 8 formation of a single-frequency relaxation oscillation pulse in the resonator; and  
 9 reducing the intracavity loss induced in the resonator upon the detection of the  
 10 relaxation oscillation pulse so that built-up gain stored in the gain medium is output from  
 11 the resonator as a output pulse at the single frequency.

1 2. The method of claim 1, wherein  
 2 the gain medium comprises a neodymium-doped solid-state material, and the  
 3 single frequency is approximately 1.05 microns.

1 3. The method of claim 1, wherein said pump source comprises a source of optical  
 2 energy.

1 4. The method of claim 1, wherein said pump source comprises a flashlamp.

1 5. The method of claim 1, wherein said pump source comprises one or more laser  
 2 diodes.

1 6. The method of claim 1, wherein the resonator includes a Q-switch and polarizer,  
 2 and said reducing comprises controlling the Q-switch.

1 7. The method of claim 1, wherein the resonator includes an electronically  
 2 controlled Pockels cell, and said reducing comprises controlling the Pockels cell.

- 1    8.     The method of claim 1, including generating a plurality of output pulses having  
2    substantially constant pulse amplitude and pulse width by repeating said inducing,  
3    building up and reducing steps.
- 1    9.     The method of claim 1, wherein the output pulse has a pulse width of less than 30  
2    nanoseconds, full-width half-maximum.
- 1    10.    The method of claim 1, wherein the resonator includes an output coupler having a  
2    controllable reflectivity, and including controlling the reflectivity of output coupler to  
3    establish a desired pulse width.
- 1    11.    The method of claim 1, wherein the resonator includes an output coupler  
2    comprising a polarizing beam splitter, and including controlling the reflectivity of output  
3    coupler by controlling polarization inside the resonator.
- 1    12.    The method of claim 1, wherein the resonator includes an output coupler  
2    comprising a polarizing beam splitter, and said inducing intracavity loss includes setting  
3    an amount of intracavity light that is transmitted by the polarizing beam splitter.
- 1    13.    The method of claim 1, wherein the resonator includes an output coupler  
2    comprising a polarizing beam splitter, and said inducing intracavity loss includes  
3    inserting a polarization rotation element in the resonator to set an amount of light that is  
4    transmitted by the polarizing beam splitter.
- 1    14.    The method of claim 1, wherein the resonator includes an electronically  
2    controlled Pockels cell, and the resonator includes an output coupler comprising a  
3    polarizing beam splitter, and including controlling the reflectivity of output coupler by  
4    controlling polarization inside the resonator using the Pockels cell.

1 15. The method of claim 1, wherein the resonator includes an electronically  
2 controlled Pockels cell, and said reducing comprises controlling voltage pulses applied to  
3 the Pockels cell, and wherein the resonator includes an output coupler comprising a  
4 polarizing beam splitter, and including controlling the reflectivity of output coupler by  
5 controlling the voltage pulses applied to the Pockels cell during said reducing.

1 16. The method of claim 1, including detecting an onset of the relaxation oscillation  
2 pulse prior to a peak of the relaxation oscillation pulse, at a point occurring at less than  
3 5% of average peak power of such pulses.

1 17. The method of claim 1, including detecting an onset of the relaxation oscillation  
2 pulse prior to a peak of the relaxation oscillation pulse, at a point occurring at less than  
3 1% of average peak power of such pulses.

1 18. The method of claim 1, wherein the resonator includes a Q-switch and a polarizer,  
2 and including detecting an onset of the relaxation oscillation, and the reducing includes  
3 applying a control signal to the Q-switch in response to the detected onset prior to a peak  
4 of the relaxation oscillation pulse.

1 19. The method of claim 1, including positioning an aperture within the resonator to  
2 allow a single transverse mode in the output pulse.

1 20. The method of claim 1, wherein the resonator comprises a ring having an odd  
2 number of reflectors.

1 21. The method of claim 1, wherein the resonator comprises a ring, an including  
2 suppressing oscillation in one direction within the ring with components acting as an  
3 optical diode.

1 22. A laser system, comprising:  
2 a laser resonator, comprising an output coupler;

3 a Q-switch in the resonator;  
4 a gain medium in the resonator;  
5 a source of energy, coupled with the gain medium, to pump the gain medium;  
6 a detector, coupled with the resonator, to detect oscillation energy in the  
7 resonator; and  
8 a controller, coupled to the source of energy, the Q-switch and the detector, to set  
9 conditions inducing loss in the resonator at a level allowing build up of gain in the gain  
10 medium to produce a relaxation oscillation pulse, and to decrease loss resonator using the  
11 Q-switch in response to detection of the relaxation oscillation pulse, so that an output  
12 pulse having a single frequency is generated.

1 23. The system of claim 22, wherein said output coupler comprises a controllable  
2 output coupler, and the controller increases reflectivity of the output coupler while  
3 decreasing loss in the resonator.

1 24. The system of claim 22, wherein said output coupler comprises a polarizing beam  
2 splitter.

1 25. The system of claim 22, including an etalon in the resonator arranged so that  
2 reflections of undesirable wavelengths are not coupled back into the resonator.

1 26. The system of claim 22, including a set of etalons in the resonator adapted to  
2 restrict oscillation to a single longitudinal cavity mode.

1 27. The system of claim 22, wherein the Q-switch comprises a Pockels cell, and the  
2 output coupler comprises a polarizing beam splitter.

1 28. The system of claim 22, wherein the gain medium comprises a neodymium-doped  
2 solid-state material, and the single frequency is approximately 1.05  $\mu\text{m}$ .

- 1 29. The system of claim 22, wherein said pump source comprises a source of optical  
2 energy.
- 1 30. The system of claim 22, wherein said pump source comprises a flashlamp.
- 1 31. The system of claim 22, wherein said pump source comprises a laser diode.
- 1 32. The system of claim 22, wherein the detector detects an onset of the relaxation  
2 oscillation prior to a peak of the relaxation oscillation pulse.
- 1 33. The system of claim 22, wherein the detector detects an onset of the relaxation  
2 oscillation, and the controller applies a control signal to the Q-switch in response to the  
3 detected onset.
- 1 34. The system of claim 22, wherein the resonator is arranged as an optical ring, and  
2 including optical components in the resonator acting as an optical diode.
- 1 35. The system of claim 22, wherein the resonator is arranged as an optical ring  
2 having an odd number of reflectors.
- 1 36. The system of claim 22, wherein the resonator is arranged as an optical ring  
2 having an odd number of reflectors, including a flat reflector having an adjustable mount  
3 setting an angle of reflection, whereby adjustments of a length of the optical ring can be  
4 made by adjusting the angle of reflection of the flat reflector.
- 1 37. The system of claim 22, including a transverse mode limiting aperture in the laser  
2 resonator.
- 1 38. The system of claim 22, wherein the output coupler comprises a polarizing beam  
2 splitter, and including a polarization rotation element in the resonator to set an amount of  
3 light that is transmitted by the polarizing beam splitter during build up of gain.

1 39. The system of claim 22, wherein said output coupler comprises an output coupler  
2 having an adjustable reflectivity, and the controller sets an adjustable reflectivity of the  
3 output coupler to establish a pulse width.

1 40. The system of claim 22, wherein the Q-switch comprises a Pockels cell, and the  
2 output coupler comprises a polarizing beam splitter, and the controller applies an  
3 adjustable voltage to the Pockels cell when reducing loss in the resonator, the adjustable  
4 voltage establishing an amount of reflectivity of the output coupler to establish a pulse  
5 width.

1 41. The system of claim 22, wherein the output coupler comprises a polarizing beam  
2 splitter, and including a polarization rotation element in the resonator to set an amount of  
3 light that is transmitted by the polarizing beam splitter during build up of gain.

1 42. A laser system, comprising:  
2 a laser resonator arranged as an optical ring, comprising a polarizer and a  
3 polarizing beam splitter arranged as an output coupler;  
4 an optical diode in the resonator;  
5 one or more etalons in the resonator;  
6 a Pockels cell in the resonator;  
7 a gain medium in the resonator;  
8 a source of energy, coupled with the gain medium, to pump the gain medium;  
9 a detector, coupled with the resonator, to detect oscillation energy in the  
10 resonator; and  
11 a controller, coupled to the source of energy, the Pockels cell and the detector, to  
12 set conditions inducing loss in the resonator at a level allowing build up of gain in the  
13 gain medium to produce a relaxation oscillation pulse, and conditions decreasing loss  
14 resonator using the Pockels cell in response to detection of onset of the relaxation  
15 oscillation pulse, so that an output pulse having a single frequency is generated, and  
16 applying an adjustable voltage to the Pockels cell to adjust polarization within the

17 resonator and thereby reflectivity of the polarizing beam splitter arranged as the output  
18 coupler, to set a pulse width during said conditions decreasing loss.

1 43. A method of operating a laser to obtain an output pulse of laser radiation having a  
2 single wavelength, the laser including a resonator arranged as an optical ring, a gain  
3 medium positioned inside the resonator and a pump source, the method comprising:  
4 suppressing oscillation in one direction within the ring with components acting as  
5 an optical diode;  
6 suppressing oscillation within the ring at wavelengths other than the single  
7 wavelength;  
8 using a polarizing beam splitter as an output coupler;  
9 setting polarization inside the resonator to induce an intracavity loss into the  
10 resonator, the loss being an amount that prevents oscillation during a time that energy  
11 from the pump source is being stored in the gain medium;  
12 building up gain with energy from the pump source in the gain medium until  
13 formation of a single-frequency relaxation oscillation pulse in the resonator; and  
14 changing polarization inside the resonator to reduce the intracavity loss induced in  
15 the resonator and to set a reflectivity of the polarizing beam splitter upon the detection of  
16 the relaxation oscillation pulse so that built-up gain stored in the gain medium is output  
17 from the resonator as a output pulse at the single frequency having a pulse width  
18 determined by the changed polarization.

1 44. A method for laser shock peening surfaces of work pieces, comprising:  
2 producing a sequence of seed pulses having a single wavelength, with  
3 substantially constant amplitude and pulse width;  
4 supplying the sequence of seed pulses to a laser amplifier to induce a sequence of  
5 higher energy output pulses having said single frequency; and  
6 positioning said work pieces in cooperation with said output pulses to peen target  
7 regions on said surfaces.

- 1 45. The method of claim 44, wherein said sequence of seed pulses has an amplitude  
2 with less than 5% variation during said positioning to peen the target regions on said  
3 surfaces.
- 1 46. The method of claim 44, wherein said sequence of seed pulses has pulse width  
2 with less than 5% variation during said positioning to peen the target regions on said  
3 surfaces.
- 1 47. The method of claim 44, wherein said sequence of seed pulses has an amplitude  
2 with about 1%, or less, variation during said positioning to peen the target regions on said  
3 surfaces.
- 1 48. The method of claim 44, wherein said sequence of seed pulses has pulse width  
2 with about 1%, or less, variation during said positioning to peen the target regions on a  
3 plurality of work pieces.
- 1 49. The method of claim 44, wherein said sequence of seed pulses has a repetition  
2 rate of greater than more than one pulse per second, and maintains said substantially  
3 constant amplitude and pulse width of a source of the seed pulses without adjusting  
4 optical parameters over a significant interval, during which a plurality of work pieces is  
5 peened in a production environment.
- 1 50. The method of claim 44, including maintaining said substantially constant  
2 amplitude and pulse width without adjusting optical parameters of a source of the seed  
3 pulses, over more than three days of use on a plurality of work pieces in a production  
4 environment.
- 1 51. The method of claim 44, wherein said sequence of seed pulses maintains said  
2 substantially constant amplitude and pulse width over at least one million pulses of  
3 sequential operation in a production environment.

1 52. The method of claim 44, wherein said sequence of higher power output pulses  
2 comprises pulses having a substantially constant energy per pulse in a range from about  
3 10 to about 100 joules per pulse over at least one million pulses of sequential operation in  
4 a production environment.

1 53. The method of claim 44, wherein said sequence of higher power output pulses  
2 comprises pulses having a substantially constant pulse width in a range from about 20 to  
3 30 nanoseconds over at least one million pulses of sequential operation in a production  
4 environment.

1 54. The method of claim 44, wherein said sequence of higher power output pulses  
2 comprises pulses having a substantially constant energy per pulse in a range from about  
3 10 to about 100 joules per pulse and a substantially constant pulse width in a range from  
4 about 20 to 30 nanoseconds during use without operator intervention for a significant  
5 interval in a production environment.

1 55. The method of claim 44, wherein said sequence of higher power output pulses  
2 comprises pulses having a substantially constant energy per pulse in a range from about  
3 10 to about 100 joules per pulse and a substantially constant pulse width in a range from  
4 about 20 to 30 nanoseconds during use for at least 3 days in a production environment.

1 56. The method of claim 44, wherein said producing includes using a laser including  
2 a resonator, a gain medium positioned inside the resonator and a pump source;  
3 inducing an intracavity loss into the laser resonator, the loss being an amount that  
4 prevents oscillation during a time that energy from the pump source is being stored in the  
5 gain medium;  
6 building up gain with energy from the pump source in the gain medium until  
7 formation of a single-frequency relaxation oscillation pulse in the resonator; and  
8 reducing the intracavity loss induced in the resonator upon the detection of the  
9 relaxation pulse so that built-up gain stored in the gain medium is output from the  
10 resonator in the form of the output pulse.